

**Some
plain talk
from
Kodak
about
sound
recording
tape**

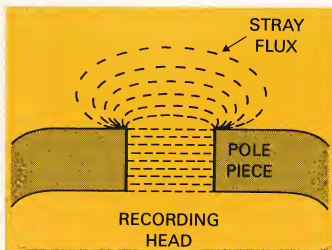


all about magnetic sound recording ...how it works, why it works

The principles involved in sound recording are simple. It's just that there are a lot of them. That's what makes it all seem complicated. But each fact taken individually is, as a rule, relatively easy to understand. Tape recording works because magnets exist and behave the way they do. Remember playing with toy magnets? Use a big magnet and it will attract heavier items than will a smaller magnet. Large magnets will also act much faster than smaller ones. The attraction that a magnet has for a piece of iron varies with distance. Hold it far away and the attraction is weak. Close up—strong! Magnetism can also be transmitted. Rub a magnet against a piece of iron and you've converted the iron into a magnet. And this brings us to the "why" of it all. A magnet is magnetic because the polarity (direction of magnetism) is the same for most of its molecules.

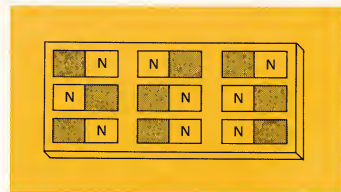
That is, most of the positive ends (north poles) face one way; most of the negative ends (south poles) face the other. The stronger the field of the original magnet, the more particles will be oriented and the greater the degree of orientation. *Keep this fact in mind. It is critical!*

Take a look at your recorder. As you follow the path the tape takes from supply to take-up reel, you note that it passes over three heads. The first is the erase head, a miniature bulk eraser which, during recording, eliminates any previous recording. Next is the record head which puts a new signal on the tape. The third is the playback head. Sometimes a single, dual-purpose head combines the record and playback functions.



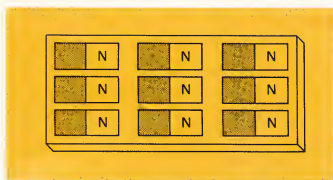
The record head is simply an electromagnet, a horseshoe-shaped piece of soft iron with opposite windings of wire on each side. This gives it its north and south poles. During the recording process, the amplified electrical a-c pulse passes through these windings and induces corresponding a-c magnetic fields (flux) around the head. The strongest flux lines are between the two pole-pieces (in the head gap). However, there is a certain amount of leakage outside the gap. *Fortunately*, for it is only this external flux that is useful for magnetic recording.

Let's take a look at how the magnetic recording process works. Before reaching the recording head, north and south poles of the "magnets" in the tape are randomly oriented.



The tape is thus in an *erased* condition. As it passes through the recording flux, there is a general statistical re-orientation of the poles. But this general re-orientation doesn't last for long because, you'll remember, the magnetic flux is rapidly alternating. Therefore, no permanent recording is done until after a section of the tape escapes the influence of the magnetic field. In other words, the polarity at any given point on the tape is continually "flip-flopping" until a point is reached where the strength of the flux is insufficient to reverse polarity. It is here, only, that information is recorded. This explains the reason why all recording takes

The cover picture is reproduced from an X-ray of a roll of Kodak tape and component parts of a tape recorder.



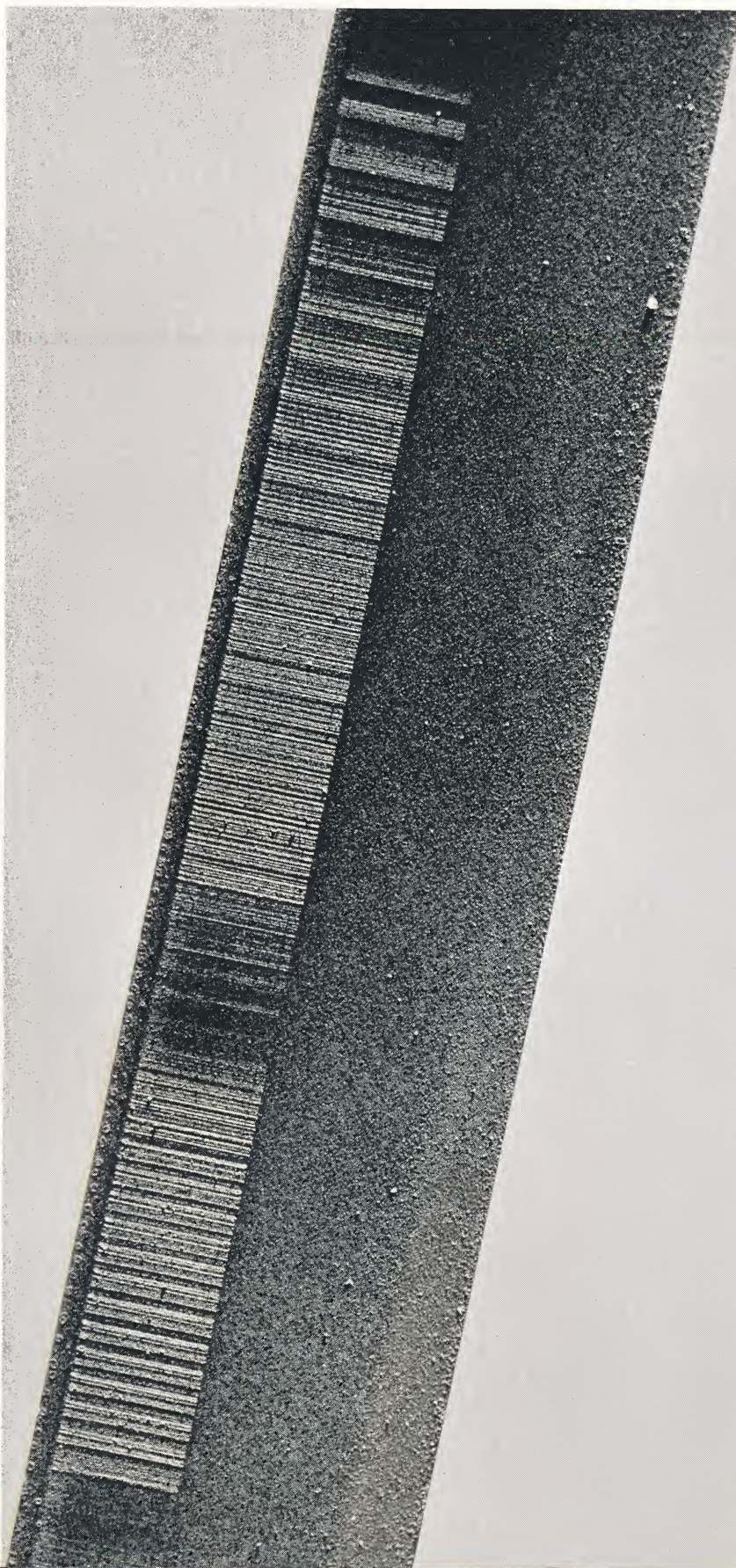
place on the trailing edge of the record head. The number of polar re-orientations throughout the depth of the oxide coating determines the volume level on playback, while the spacing of these reversals along the length determines the frequency.

Maybe it would help to actually see what this induced magnetism looks like. The picture to the right is what the word KODAK looks like. (It is recorded on just one track.) We've dusted some iron powder on the recorded portion of the tape. See the syllables. Each tiny peak or valley in the sound wave is represented by a pulse on the tape. Visually we can't distinguish between a peak and a valley, but the polarity of their magnetic fields is opposite.

If it were possible to view the cross section of a piece of recorded tape, we would note a strong concentration of magnetic force within the oxide layer. But just as with the recording head, a certain amount of stray flux radiates above the tape surface and is the only part of the tape's magnetism that is useful to us. It is these stray fields that induce voltage changes in the playback head. These pulses are fed from the head to the amplifier and then into the speaker.

The quality of the sound reproduced depends both on the recorder's electronic and speaker systems as well as the quality of the recorded tape. It's fair to say that Kodak tape will bring out the best in any recorder.

At best, this outline of the recording process is but a gross simplification, but it is accurate in principle. To learn more about tape, read on.



all about magnetic domains and sound brilliance

As exotic as the many performance parameters of sound tape might be, it all still depends upon gamma ferric oxide particles dispersed throughout a resin binder. Many of the tape's magnetic characteristics depend largely on the size, shape and orientation of these particles. Frequency response, signal-to-noise ratio and general sensitivity are all interrelated, not just to one another, but to how close to optimum these needles of gamma oxide are handled.

Let's see just what's involved.

Visualize a Basket Filled With a Few Million Needles

They have all been magnetized so they are clinging together in disoriented clumps. The problem? Just take them all apart, lay them along parallel lines so they are all similarly oriented and their magnetic fields all reinforce one another. Oh, one more detail. These needles measure 1 micron by .2 microns, so, of course, they are somewhat delicate. One more point. Don't break any of them. The lengths are critical. For every broken or disoriented needle, H.F. response and signal-to-noise ratio will be affected. Also, every time

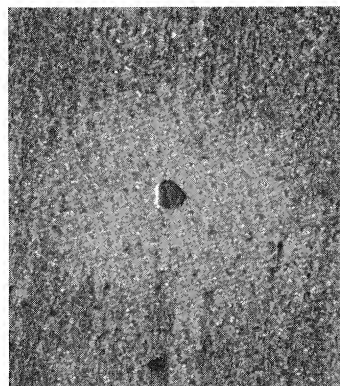
one needle touches another, making electrical contact, sensitivity suffers.

Fortunately, for about 85 years we've been solving problems that are kissin' cousins to this one in the coating of photographic emulsions. Photographic emulsions are generally considered to be far more critical than sound tape in terms of physical characteristics. But we think that tape made to the gnat's-hair specifications of a photographic film is a better tape. And we proceed on just this basis.

We separate the needles in a big-shouldered machine called a ball mill, a massive stainless steel drum that contains two million ball bearings. When the drum turns, the ball bearings tumble. Into the drum goes the binder which will act as a suspension for the oxide. Then in goes the oxide. As the ball bearings tumble, they actually shear the honey-like suspension, separating the individual needles, coating them with the binder so they can't make electrical contact with one another. This process really takes horsepower—and lots of it! It's like the world's biggest taffy-pull.

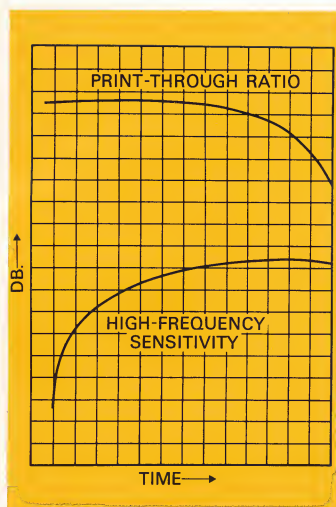
Now comes the critical part. If you stop milling too soon, you'll have clumps of needles in the dispersion and end up with a rough-surfaced tape. It's easy to fall in love with the idea that the shorter the time you mill, the higher production will be, since that's the way to make tape cheaper. But we don't play that sort of music around here. We never cut milling time, and we can prove it.

Take any well-worn tape. Look at it so that light reflects off the surface. See those glossy spots surrounded by a dull ring? They are nodules—high spots produced by clumping of the oxides. They were caused by too short a milling time. No good.



In actual practice, these nodules cause accelerated head wear and degrade high-frequency response besides showing up on the tape as noise. Now check a well-worn Kodak tape. If you can't find a clumping immediately, check the entire roll. There must be one there, somewhere. Or must there?

Milling for too long a time is just as bad as stopping milling too soon. Here's why. If you mill too long, you'll start breaking up the individual needles. Best performance is to some extent dependent on the dimensions of the needles. That is, the ratio of length to width. If you break the needles into smaller particles by milling too long, you'll get forms that are more cube-like than needle-like.



oxide particles are deposited in random fashion. While the coating is still soft, the tape is passed through a very strong magnetic field that physically orients the needles in the lengthwise direction . . . sort of like row after row of freight cars in freight trains. When the solvents are driven from the dispersion, the needles are anchored in position. Thus, when a magnetizing force is applied to a tape, the needles themselves will not move. Only their polarity will change.

At Eastman Kodak, coating is uniform to within a few millionths of an inch. No, that's

not a typographical error—we mean it. Six decimal places. This may be a new standard of precision for sound tape. But remember, we've been doing this sort of coating for years on film. While it's not exactly as easy as falling out of bed, it is a technique which we have down cold. And it makes a dramatically significant difference in performance. Sound brilliance is what you get when you do everything right. And the righter you do it, the better the sound.

Cubes of iron oxide have pretty awful characteristics in terms of their magnetic parameters. Some of the very first magnetic tapes ever produced had cubes. Remember? You had to operate at a speed of 30 inches to get anything approaching good sound, and even at that, it didn't approach it very closely.

In addition, these cubes do all sorts of other distressing things, such as changing the bias requirements of the tape, and elongating the hysteresis curve, cutting sensitivity, and giving pretty awful print-through characteristics besides.

Milling time is critical to about one percent, and temperature and humidity are even more critical than this.

Once the milling operation is complete, the suspension is filtered to remove any clumps that might have remained. Then the real tough problem starts. Coating. All you have to do is to take this honey-like mass and lay it along a flexible base nice and evenly. Problem is, the needles try to re-clump after filtering! To prevent this, we developed our new "R-type" binder. It never re-clumps. And it always stays where it's put. No sagging, ever. And this means it can be handled with precision.

When the oxide dispersion is first coated on the base, the

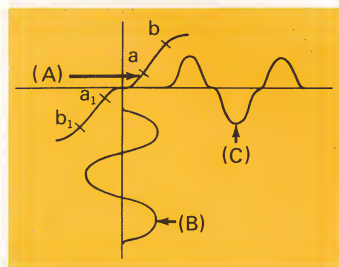
This miniature ball mill is used by research physicists to develop new, more efficient dispersions.



all about bias

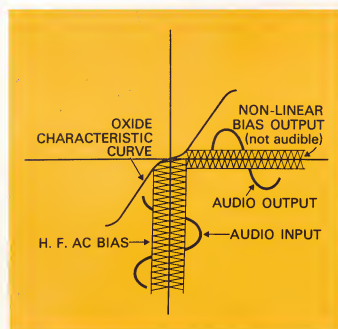
Ever heard the story about the pilot on his first solo flight? Unfortunately the engine failed. But fortunately he had a parachute. But unfortunately the chute failed to open. But fortunately he landed in a haystack. But unfortunately there was a pitchfork in the haystack. Except for the unhappy ending, this might be the story of how gamma ferric oxides respond to magnetic fields. Everything about it is fortunate with one exception. *Linearity*. The oxide needles used in all such coatings have atrocious linearity characteristics. Feed in a clean, pure sine wave—without *doing* anything about linearity—and out comes a non-sinusoidal complex waveform that looks something like a demented snake trying to bite its own head off. How does it sound? About as pleasant as Junior's first violin lesson.

How, then, is magnetic recording possible. Fret not—there's a way out. This entire problem is solved by one wonderful, mysterious phenomenon called bias. The transfer curves tell the story.



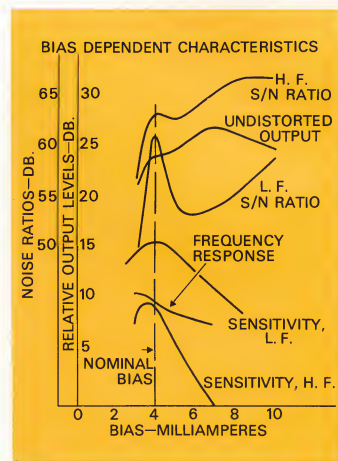
The slightly twisting curve A represents the oxide response. Curve B is a pure sine wave input. At C we have the response curve . . . a mess.

The reason why curve C looks the way it does is because the sine wave input is affected by the non-linear characteristics of the gamma ferric oxides. But look closely at curve A again. Note that while the oxide performance is non-linear when taken over the entire length of the curve, we can find linearity over selected sections (a-b and a₁-b₁). In other words, we can get rid of our distortion if we can put the signal on the linear sections of the oxide's characteristic curve. And that is exactly what bias does. It is a minute amount of a-c current, independent of signal, deliberately applied to the recording head. It "lifts" the signal away from the convoluted central area of the characteristic curve and moves it out to the linear areas.



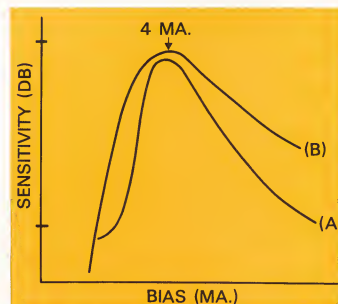
The amount of bias (that is, the current in milliamperes) that is applied to the recording head is extremely critical if top performance is to be achieved. In fact, the choice of bias affects every important electrical parameter . . . low- and high-fre-

quency sensitivity, frequency response, undistorted output, and low- and high-frequency signal-to-noise ratios. The bias dependent characteristics for these properties are plotted on the curve below.



The idea is to select a bias current that will maximize each property. For the recorder on which these tests were made, optimum bias is about 4 milliamperes. As a general rule, the biasing field should be about ten times the maximum audio field that can be used without excessive distortion. The biasing frequency should be at least five times the highest expected audio frequency.

The shape of these various bias dependent curves is also very meaningful. Compare the shape of these two curves.



The steep curve A represents low-frequency sensitivity (measured in dbs) at varying bias levels for many tapes. Note that you get good performance pro-

viding you have a bias setting of about 4 milliamperes. (Curves for the other magnetic parameters are similar in shape and all peak at about the same bias level.) Vary one milliampere and you "fall off the curve" and suffer severe losses in sensitivity. Now look at the broader

curve B. You can vary a milliampere with hardly any change in performance at all. Here's the point. *Kodak tape is so formulated that it has that broad curve!* It gives you top performance even though your bias setting isn't perfect. And if your tape recorder is more than a

year old, then chances are, enough bias shift has taken place to push you off the cliff. That's why we designed this broad bias curve right into the tape. You need it. It's just one more way that Kodak tape gives you an extra bit of assurance of top performance.



all about sensitivity and frequency response

Controlling every electrical factor involved in the making and using of sound tape is a bit like trying to watch a three-ring circus . . . it can be done, but you need fast eyeballs. To give you a picture of a few things that need looking after, it might be a good idea to list the factors as a group and then go over them one at a time. They are:

- High-Frequency Sensitivity
- Low-Frequency Sensitivity
- Frequency Response
- Print-Through
- Undistorted Output
- Modulation Noise—Low Frequency
- Modulation Noise—High Frequency
- Signal-to-Noise Ratio—High Frequency
- Signal-to-Noise Ratio—Low Frequency
- Saturated Output

Sensitivity means the same in tape technology that it does under any electronic condition: the degree of output for a given input. We put in a 400-cycle signal and measure the output. The result is low-frequency sensitivity.

We choose 400 cycles for a number of good reasons. Let's do a little arithmetic. A 400-

cycle note recorded at 15-inches-per-second gives us a wave length that the tape "sees" of

$$\frac{\frac{\text{inches}}{\text{second}}}{\frac{\text{cycles}}{\text{second}}} = \frac{\text{inches}}{\text{second}} \times \frac{\text{second}}{\text{cycles}} = \frac{\text{inches}}{\text{cycle}} \quad \text{which is wave length } (\lambda)$$

THUS

$$\frac{\frac{15 \text{ inches}}{\text{second}}}{\frac{400 \text{ cycles}}{\text{second}}} = \frac{15 \text{ inches}}{\text{second}} \times \frac{\text{second}}{400 \text{ cycles}} = .0375 \frac{\text{inches}}{\text{cycle}}$$

roughly .0375 inches, and by a happy coincidence this wave length penetrates the entire depth of the oxide coating, but not the support material. Why must the wave penetrate the entire coating for a low-frequency test? Simple. Everything else being equal, low-frequency response is a function of the thickness of the coating. The thicker the coating, the better the bass response. If you want a tape that is flat way down low, then we have to test at a frequency that penetrates the entire coating. We choose 400 cycles instead of, let's say, 20 cycles because the 400-cycle note tells us just as much—and has an added advantage. An engineer can hear 400 cycles, so we have audio monitoring as well as instru-

mented observation on the face of a scope.

Just as the low-frequency sensitivity test gives us an idea about oxide thickness, the high-frequency test gives us a fairly accurate picture as to just how smooth the surface of the tape is. Good high-frequency response is impossible on a tape having a rough surface. For one thing, high frequencies affect fewer oxide particles. If the tape surface is rough, the low points will represent gaps in the oxide and cause a loss of H.F. response. We test our high-frequency sensitivity at 15,000 cycles. At 15 ips this gives us a recorded wave length of 1 mil (.001 inches).

Now at this high frequency (short wave length) we are getting a skin effect. We are recording only on the surface of the tape. If any roughness is present, big troubles result. For example: If you have a surface condition where the amplitude of the roughness is just .0001 inches, you will lose 5.5 db in high-frequency response! While you are recovering from that startling bit of news, let's rephrase the catastrophe. It takes a surface variation of just one ten-thousandth of an inch to knock down high-frequency response by a factor of almost four!

For those interested, here's the formula:

$$\text{Loss (db)} = \frac{55d}{\lambda} \quad \text{where } d \text{ equals the spacing distance and } \lambda, \text{ of course, equals the wave length.}$$

If you haven't suspected it up to now, we are working toward making a vital point about tape technology. And here it is. KODAK Sound Recording Tape has a surface that is unsurpassed in smoothness. The mechanics of surfaces is covered more fully in another section of this booklet. Surface smoothness for Kodak tape varies no more than 25 to 50 millionths of an inch from a theoretically perfect plane. *That's smooth!*

A frequency response calculation is merely the arithmetic

subtraction of high-frequency sensitivity from low-frequency sensitivity. Ideally the response is zero because we want to hear all the vigor and nuances of the original. Of course, frequency response is the *product* of the responses of the microphone, the recording and reproduce circuits and the tape. Our objective as a tape manufacturer is to give you enough output at all frequencies so that you can achieve flatness without straining the noise and distortion levels of your components.

It's quite an easy matter to juggle the characteristics of the oxide around so that frequency response is nice and flat. For instance, if your oxide has poor high-frequency sensitivity, you can reduce the thickness of the oxide layer. This will degrade L.F. sensitivity, and thus effect a flat response. But is the resulting L.F. loss worth it? We don't think so. That's why we designed our coating to give us superior low- and high-frequency sensitivities, as well as a nice flat response.



all about print-through and undistorted output

Put a magnet near a piece of iron and the iron will become magnetized, too. That's print-through. With sound recording tape, it's simply signal transfer between adjacent layers of the wound roll. Print-through shows up on playback as a series of distressing pre- and post-echoes.

Print-through is a problem . . . with solutions

The amount of print-through you get varies with environmental conditions. Print-through is more pronounced at temperatures above 90 degrees F. than at lower temperatures. High humidity doesn't help much either. If the tape is stored "tails-out" and then played back in the normal manner, the stronger pre-echo will *follow* the recorded signal and thus be less obvious. But the echo is still there and still annoying. Some people "exercise" their tapes—by winding and rewinding several times—during an extended storage period. This helps, but what a nuisance! There's only one way to beat print-through and that's to start with a tape that doesn't print very much to begin with!

Print-through tests are a million laughs. We record a series of tone bursts . . . saturation, of course. We then cook the tape for 4 hours at 65 degrees Centigrade—that's 149 degrees F.—and then measure the amplitude of the loudest pre- or post-echo. The spread between the basic signal and this echo is called the signal-to-print-through ratio. The higher the number, the better the results. Most of the general-purpose tapes you'll find have a ratio of 49-50 db. Low-print tapes average about 52 db. Our general-purpose tape (Type 31A) tests out at 53 db . . . so, you can see, it functions as both a general-purpose tape and a low-print tape—and at no extra cost. Unwanted print-through increases with thicker oxide layers. High-output tapes with their thicker coatings have pretty awful print-through ratios—generally around 46 db. Kodak's high-output tape (Type 34A) has something special here, too. A ratio of 49 db—equal to most general-purpose tapes.

The Kodak solution to the print-through problem starts with the selection of the iron oxide. In order to achieve low print-through, the oxide needles must have the proper crystalline structure. Kodak's oxide needles have that structure. But you can't stop here. To keep print-through down you have to exercise extreme care in the manufacturing process. Milling, for instance, is very critical. You've already seen how milling time affects print-through. But other factors in the milling process are equally important. Take the speed at which the ball mill turns. It can't be rotated too fast, otherwise the needles will be broken up, and broken needles, you know, exhibit horrible print-through behavior. If you rotate the mill too slowly, the oxide and other ingredients will not be blended uniformly. Other factors such as temperature and the composition and viscosity of the ingredients must also be critically controlled. One more thing, you've got to make sure the needles end up the same size (.1 x .8 microns) if print-through is to be kept down. The most important single contributor to low print-through is the binder that holds the oxide particles in suspension. The *composition* of a binder contributes nothing magnetically to a tape's print-through ratio. What a binder *should* do is completely coat each individual oxide needle, thus preventing the particles from making electrical contact. And that is just what our "R-type" binder does. And that is why Kodak tape has such outstanding print-through characteristics.

Undistorted output is a key parameter

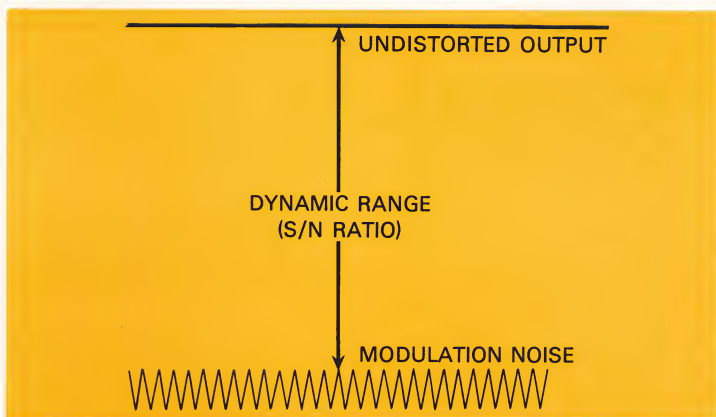
Distortion (or lack of) is the very heart of the entire high fidelity problem. It's easy to evaluate distortion on, let's say, an amplifier. You put it under load, drive it to just before clipping, read the volts out over the ohms

load and you've got power out. The distortion at that power figure is it. But with tape, it is a bit more of a problem. But we solve it in a similar way. We drive the tape until it hollers "uncle" and use that point as a benchmark. Here's the procedure. Increase the 400-cycle signal input until 2% third harmonic distortion ("uncle") is reached. We use 400 cycles because we want to affect the entire oxide depth. The more input signal needed to reach "uncle," the higher the undistorted output.

Now, before you put on boxing gloves with a "wadayamean-undistorted output at two percent," allow an explanation. The two percent is a reference that gives us a complete picture as to oxide performance on this parameter. At normal recording levels, tape distortion may be .05% . . . or even less. Let's go back to that amplifier we were testing a few moments ago. Let's say that we decided, arbitrarily, to rate the power of that amplifier at the two percent level. We would get a higher output figure than at the listening level. But the amplifier wouldn't really change. Same with tape. Two percent is a good test figure because it tells us so much about the .05% performance you will be getting at the levels at which you work.

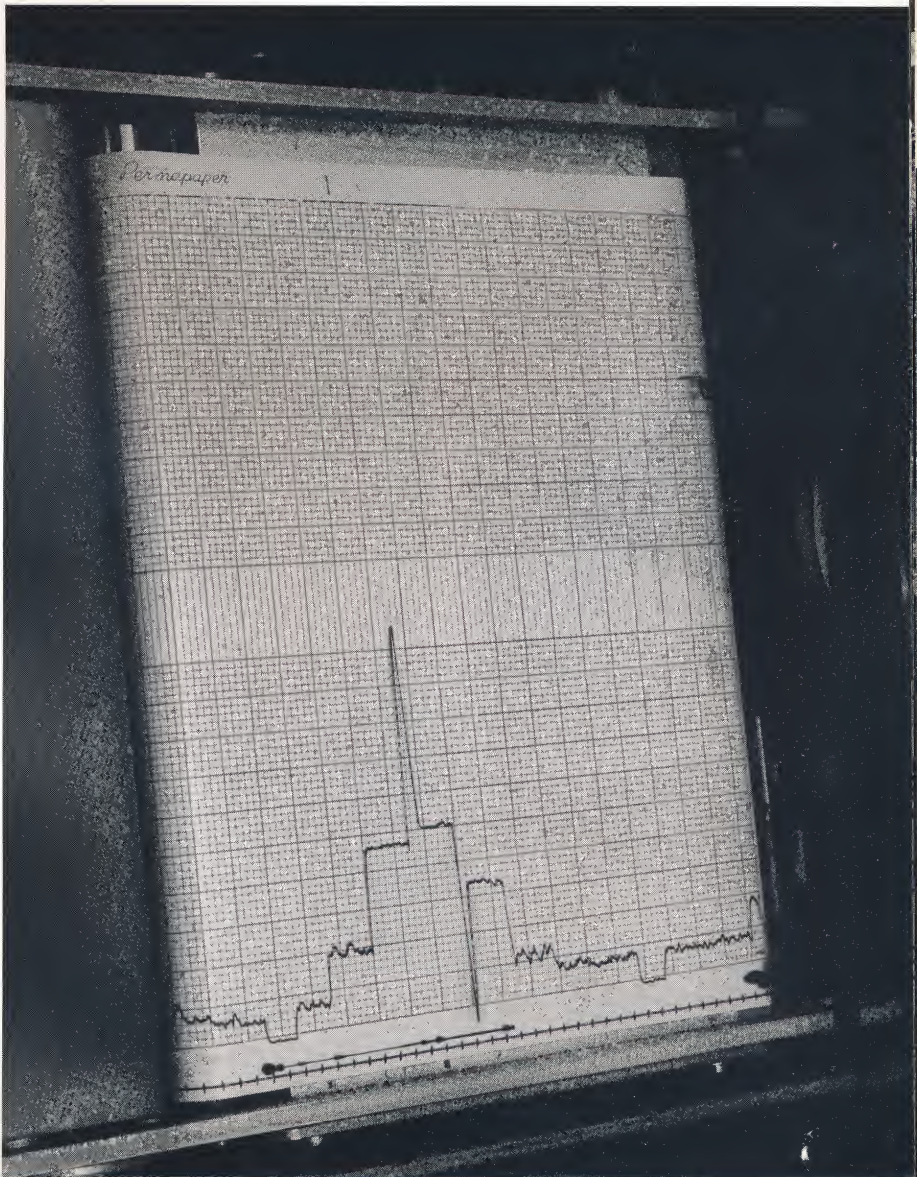
Here's another very important contribution made by the undistorted output figure. It can be directly related to the dynamic range (signal-to-noise ratio) of the tape. Think of it this way. The higher the undistorted output the greater the gap between a no-signal and a maximum-signal figure. Look at the chart. The upper limit is undistorted output. The lower is the "mud" or noise inherent in the tape and the recorder. It's that simple.

Graphic representation of a print-through test. The central "blip" is the recorded signal—about 54 db above the strongest echo.



Before we get into a detailed discussion of the "mud"—modulation noise as some more formal types tend to call it—let's take a parting shot at the undistorted output situation. Kodak's

general-purpose tape has an undistorted output of from 1-3 db higher than any comparable tape—yet its print-through ratio is better than other premium-priced low-print tapes!

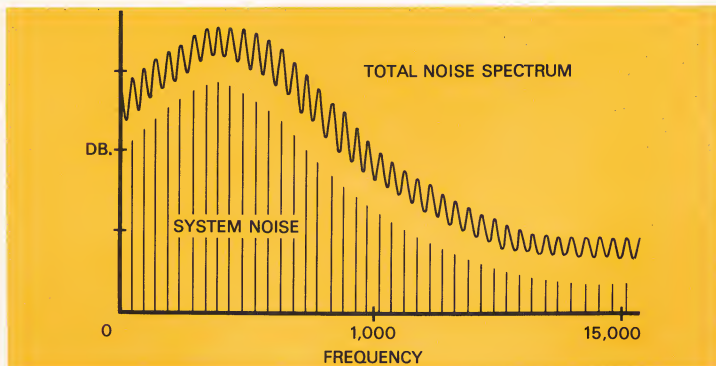


all about signal-to-noise ratios, saturation output and uniformity

Notice how taking a modulation noise average for the entire spectrum results in a figure that is lower than the L.F. figure and higher than the H.F. figure. How is this important? Here's how. If we use the modulation noise level from the low-frequency range (A) we get a poor dynamic range and signal-to-noise ratio. We get a moderate one from the average (B) and a great one from the H.F. figure (C). There are those who would measure from C and publish this as the performance of their tape. Let them. We measure low-frequency and high-frequency mud and still come up with a dynamic range that is often as much as 6.5 db better than conventional tapes in the L.F. area, 1.5 db better in the H.F. range—even when they use their lowest figure. We are pretty proud of our silence. Shhhhhh is the word at Kodak.

There are all sorts of uncles

We said that we made tape cry "uncle" when we gave it the undistorted output test. We make it cry "uncle" again—and louder by far—when we test for saturation output. Here's how that works. We increase the input and monitor the output. When we reach a point where the output no longer increases with the input, we know that we have reached saturation, which is the point where every available oxide particle in the layer has

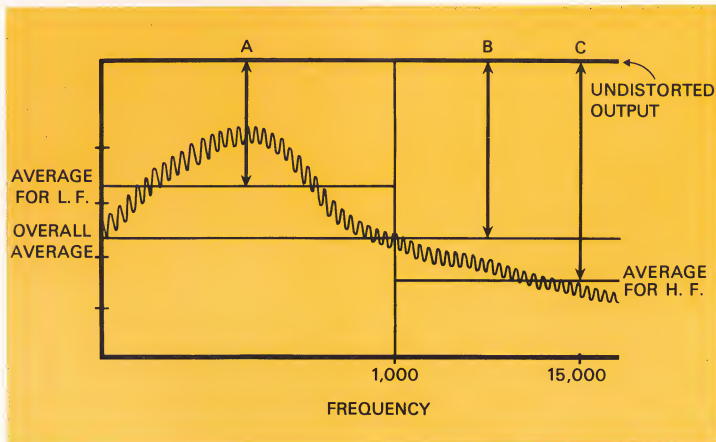


Now to modulation noise—the most discriminating test of sound tape. A close look at the "mud" that forms the lower limit of the dynamic range reveals that the recorder's electronic and transport systems are responsible for the lion's share of noise. By noise spectrum analysis we can examine noise level (in dbs.) at every frequency. Look at the graph above.

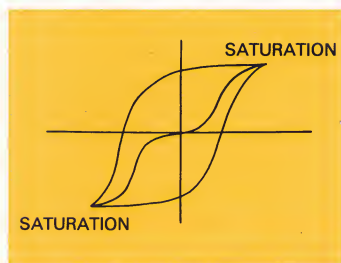
Note that there is a much higher level of modulation noise at 1,000 cycles than at 15,000 cycles. This indicates—to us, anyway—that a single-frequency modulation noise test is not the most meaningful in terms of a noise spectrum. We use two frequency bands: 0-1000 cps and 1000-15,000 cps to provide us with a low-frequency s/n ratio and a high-frequency s/n ratio.

This is a much tougher test than using a single frequency or integrating the entire spectrum.

Here's another chart that shows the effect.



been polarized. Saturation output is indicated by the flat sections of the hysteresis loop.



As a test it does not have earth-shaking implications, but it does tell us about how many oxide particles are present, which is actually a measure of the thickness and particle density of the oxide layer. We get a

figure in db and can use it to accomplish some pretty tight quality-control work over our oxide coatings.

We're pretty proud of that control, too . . . and with good reason. We make our tape so that we are well within the rigid specifications we publish. At Kodak, uniformity is a way of life. When we say sensitivity varies no more than $\pm 1/4$ db within a roll and $\pm 1/2$ db from roll to roll, we *really* mean it! This is only the uniformity of the low-frequency signal. We check high-frequency uniformity as well. In that way we can keep close tabs on the uniformity of the oxide thickness *and* the uniformity of the oxide surface.

But uniformity is more—much more—than just a word. It has plenty of practical significance. For instance, uniformity within a roll assures constant frequency response, balanced output for *all* recording tracks, and freedom from dropouts. Reel-to-reel uniformity permits inter-reel splicing without obvious changes in the level of the recorded signal. And for the professional, it means that he can find *one* optimum bias level for all rolls of tape.

You can do all these things with Kodak tape. In fact, we're so proud of the uniformity of our product, we put our name on it . . . right there on the back of the tape!



all about curl, surface hardness and cohesive peel

Between fast forward, reverse, and a few hundred screeching halts in between, tape takes a pretty awful beating, even under the best of circumstances. To stand up under this sort of strain, tape needs a degree of strength that is fairly monumental in terms of its mass. And that strength takes on many forms in many areas. The base must be strong. But not so strong that it won't break *clean* under excess emergency loads. The oxide coating must stick to the base under a broad spectrum of environments. Tape must lie flat. It must track true. It must do a variety of things that only the most critical manufacturing controls can insure. Let's review a few of the mechanical requirements along with the "why" of it all.

Tape is pretty thin stuff. Standard 1½-mil tape measures just .0015", and the triple-play variety measures a mere .0005".

It's almost impossible to cast a material that thin without having it "cup" just a bit. This tendency to cup or curl, as it is synonymously called, must be held to an absolute minimum, and there are techniques to keep it well under control. The basic cause of cupping can be traced back to the fundamental coating operation. After the oxide has been coated, the resulting combination consists of two materials, base and oxide, each having a different coefficient of expansion for temperature, humidity, modulus, and plastic flow. The result is a form of thermobar, each half of which will react differently to every change in temperature, humidity, and tension. This means that both the environmental temperature and the humidity during use will materially affect curl. The test for curl is an obvious one . . . compare the tape to a precision-ground flat surface. During the

test, temperature is held constant; however, relative humidity is varied from 20% to 70%. The resultant curl is either positive or negative.

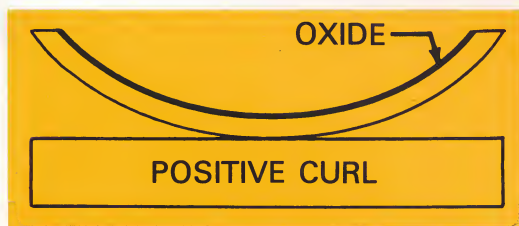
Curl is measured by determining the radius of curvature that the tape has taken. The values obtained are in special ASA curl units, which are merely reciprocal radii. Curl is never a problem with Kodak tape. Kodak has a wide range of experience with materials of this type through eighty years of film-making. Far more than any other tape manufacturer. That's one reason why Kodak tape is as flat as it is, even under extreme conditions.

Naturally harder for longer tape life

We've said curl seldom is a problem to the audiophile; however, surface hardness (or lack of) can be. Obviously, you want an oxide layer that's tough and durable and will give years of useful recording life. So how do we find out how resistant our oxide is to scratching? Simple. We scratch it. We call it a "single arm scratch test." Here's how it works. We take a moving tape and force a stylus against it. The amount of force necessary to penetrate the oxide coating gives us an indication as to the hardness of the coating. On comparative tests Kodak tapes vary from 5 to 15% harder than random samples of ordinary tapes. The reason is simple. Our "R-type" binder. The process is secret.

We make it stick so you don't get stuck

Anyone can coat an oxide on a support. But making the oxide stick together and stick to the base—that's a horse of a differ-



ent color. To test for which is strongest (cohesion, adhesion or the base), we use the "cohesive peel test." We test in the most logical way possible. We try to rip off the coating with a special type of adhesive tape. When the test is completed, three possibilities exist in terms of results: the tape may strip off the entire oxide layer leaving the clean, clear base; it may split the oxide layer leaving a reddish layer on the base and a reddish layer on

the adhesive material; or it may tear the tape. Which is the most desirable condition? Tearing the tape, of course. The point being to bond the oxide so well to the base that the bond exceeds even the tear strength of the base material. In that way you get a final product that will almost never shed its oxide. And that's the way it should be. It's the way Kodak tapes are designed. One reason why Kodak tape requires more dynes of

force than any other to separate base and oxide is our "R-type" binder plus the fact that we use a subbing layer that provides a "tooth" that insures a better bond. And this bond becomes really important when we think of the slitting problem—about which we talk next.

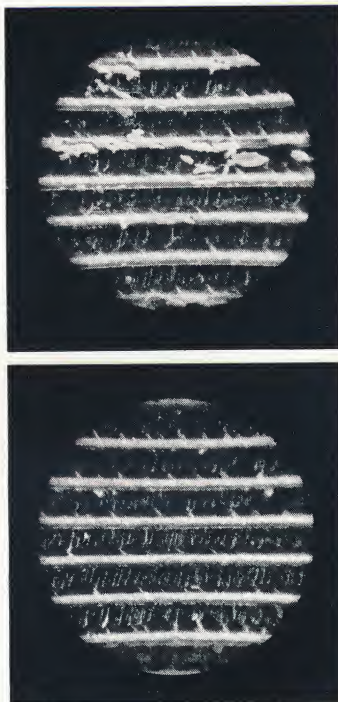
Weights are added to the platform until the sapphire needle scratches the surface of the moving tape.



all about slitting, winding and plastic flow

Tape is made in wide rolls which are slit to width— $\frac{1}{4}$ " for most audio tapes. There are three main considerations in this process: cleanliness, dimensional accuracy and trueness of cut. Cleanliness cannot be given too much consideration. When tape is slit, oxides which are not too well bonded to the base are powdered off. This action is virtually non-existent in Kodak tapes because of our "R-type" binder and special slitting techniques. This oxide powder (dirt) clogs the recording head and keeps the tape from making intimate contact, causing drop-outs, crackles and high-frequency losses. Another type of oxide dirt causes a phenomenon known as re-deposit. During a normal tape transport operation these gummy wear deposits actually penetrate the oxide layer and fuse in position. Just imagine the New York State Thruway strewn with giant boulders. Well, that's the way re-deposits appear to your recorder heads. Pleasant thought, isn't it?

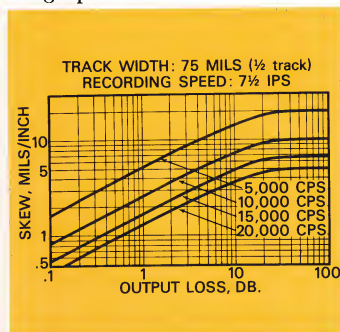
To get some idea about how Kodak tape slitting compares to ordinary slitting, take a look at these two photomicrographs. The dirt you see between the turns on the top is oxide dirt. Compare it to the virtually spotless edges of Kodak recording tape on the bottom.



**It's like splitting hairs,
only more critical**

From our 42-inch-wide master web, we have to cut 160 $\frac{1}{4}$ -inch ribbons of tape—each over two miles long. That's a lot of total mileage, especially when you think how straight and true those edges must be to assure optimum tracking on your recorder. In terms of slitting accuracy the standard specs call for a tolerance on width of $\pm .0020$ inches. We decided that that was just about double what it really should be, so we hold ours to $\pm .0010$ inches. But the really critical part of slitting is a bad guy known as weave. When a tape weaves, it passes

the head at a continuously changing skew angle. Look at the graph.



Note how losses pile up as skew angle increases up to as high as 20 mils/inch where the reproduce system fails. And as you would guess, the losses are in proportion to the frequency. Higher frequencies, higher losses. Same principle as when a recorder head is out of alignment.

Because tape is basically a plastic material, it is subject to all sorts of little annoyances. For example: Under conditions of high temperatures a phenomenon takes place called plastic flow or "creep." This is an actual flow of the plastic under heat. Especially at temperatures that exceed 90 degrees F.

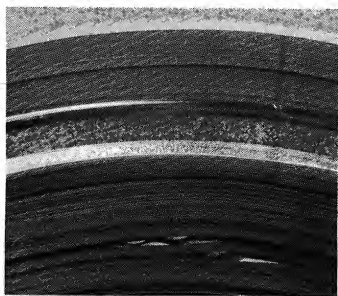
How do we check for "creep"? Well, we take a length of tape and suspend it from one end. We attach a weight to the other end and let it hang for three hours. We remove the weight and measure the recovery. We then do it all over again. This gives us a direct and valuable measure of the dimensional stability under dead-weight conditions with no shock involved. While this test is simple, it is conducted under what might be considered reasonably critical conditions. Stretch is measured to five decimal places and environmental factors such as temperature and humidity controlled to well under 1%.

There are also problems when tape is cooled to temperatures below 50 degrees F. If the tape has been wound on its reel at room temperature (about 70 de-

grees F.), then at high temperatures the roll will expand and tighten, setting up strains in the plastic material. Should the temperature drop below 50 degrees F., then the roll will go floppy and a "step" is likely to form. This seemingly innocent flaw is really quite serious.

Note that the tape step is exposed to air and its accompanying humidity. In addition, the lower part is under pressure and the upper part is not. This actually causes a change in the dimension of the tape from top to bottom. And the edge becomes fluted. This physical distortion causes great H.F. losses.

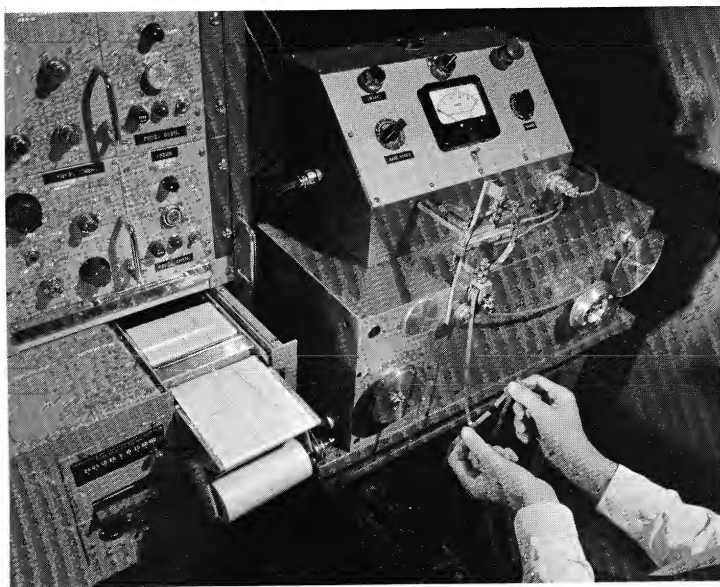
The patterns of tension set up within the roll are quite interesting. Normally, the tension at the outside of the roll will decrease until it reaches a point of zero tension about one-third the way from the core. Beyond this point the tension increases, but the direction of that force is *reversed*. Near the core the tape is in a state of compression. It's just the opposite with the outer layers. They're clockspringed. This loose, crinkled roll of tape is an example of the poor winding commonly found in unmarked, "white box" tape. Of



course, you'll never see this kind of mess in a roll of Kodak tape. From winding billions of feet of motion picture film, Kodak has developed some pretty specialized tension-control techniques. The end result, of course, is that when you get Kodak tape on a roll, you know it's wound properly — not too loose, not too tight. Just right.



all about base materials and tensile properties



Base materials have their problems, too. They must not stretch or sound distortion will result. They must be strong so that they won't break readily. But if a walloping shock comes along, they must be "short" enough to break clean without necking down and losing recorded material. They must be supple enough to be head-clinging but not so floppy they behave like wet spaghetti. Basically, two different materials are used in tape bases. Acetate and polyester. These two materials are so different that they are used for entirely different applications and do give us sufficient versatility to solve most base problems.

Polyester is a really tough material. It is a first choice when it comes to superior strength in thin coatings such as 1/2-mil materials. Therefore, where really long play is needed, polyester is the ticket. Acetate is a different story altogether. Especially our unique type of acetate which we have named "Durol." Durol base is outstanding in its yield strength and elasticity characteristics. Under emergency loads it will break clean with virtually no permanent deformation. Here's the story.

Magnetic tape is subject—day-in, day-out—to a wide variety of stresses and strains. That's why we are more than casually in-

terested in its tensile properties. For purposes of illustration, think of tape as a door spring. Put it under tension and it will stretch. When the tension is released, it will snap back to its original shape. It will, that is, unless you've stretched it beyond its yield point. For if over a certain amount of longitudinal stress has been placed on a tape, the tape will lose its ability to recover and will, in fact, remain permanently elongated. Stretch it even further and, naturally, the tape will break in two.

Deformed tape will not reproduce sound faithfully. And tape that breaks too easily is just a plain nuisance. So we set our sights high and developed a special triacetate—called Durol base—that's exceptionally tough, yet breaks clean without "necking down." In order to prove its worth and keep it that way, we established a tight set of specs for our quality-control boys—specs which were a direct outgrowth of the conditions under which a tape is to be used. For example, the shock of going from fast wind to fast rewind. Or the shock generated on a running recorder when the supply spool jams.

We think that tape should be able to take this sort of punishment routinely. So, of course, we double, triple, even quadruple the requirements! And just to make sure that the tape performs, we build torture tests that would have delighted Attila the Hun.

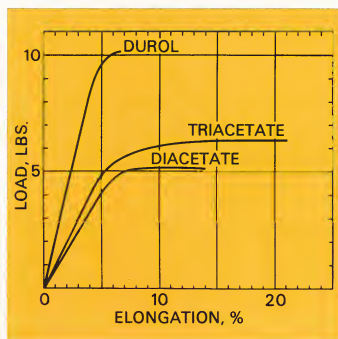
The test device to the left is outstanding in its fiendishness. It's called the High Speed Tensile Tester and is designed to break tape under load.

But like any good one-man band, it does a lot more than just one job. It not only breaks tape but gathers scads of very useful data as well—data which completely describes a tape's tensile properties. Here's how it works. It's built like a tape deck with the tape attached to one half of a solid-ring electrical strain gauge. We run the deck and then jam on the brakes on

the supply reel but keep the take-up reel going. The strain gauge takes the full load and the ring spreads and deforms. This deformation causes the gauge to change resistance and causes the d-c voltage on it to pulse. We monitor the pulse on a graph (or scope) and measure its duration. This gives us a figure of merit in terms of tensile strength.

Just how good is Durol base? Well, consider these data. Yield strength for Durol base is 47% greater than regular triacetate and 70% greater than diacetate (the two most common plastic support materials). Break strength is 43% greater than triacetate and 80% greater than diacetate. And this is the kind of test that almost duplicates actual use conditions on your tape equipment.

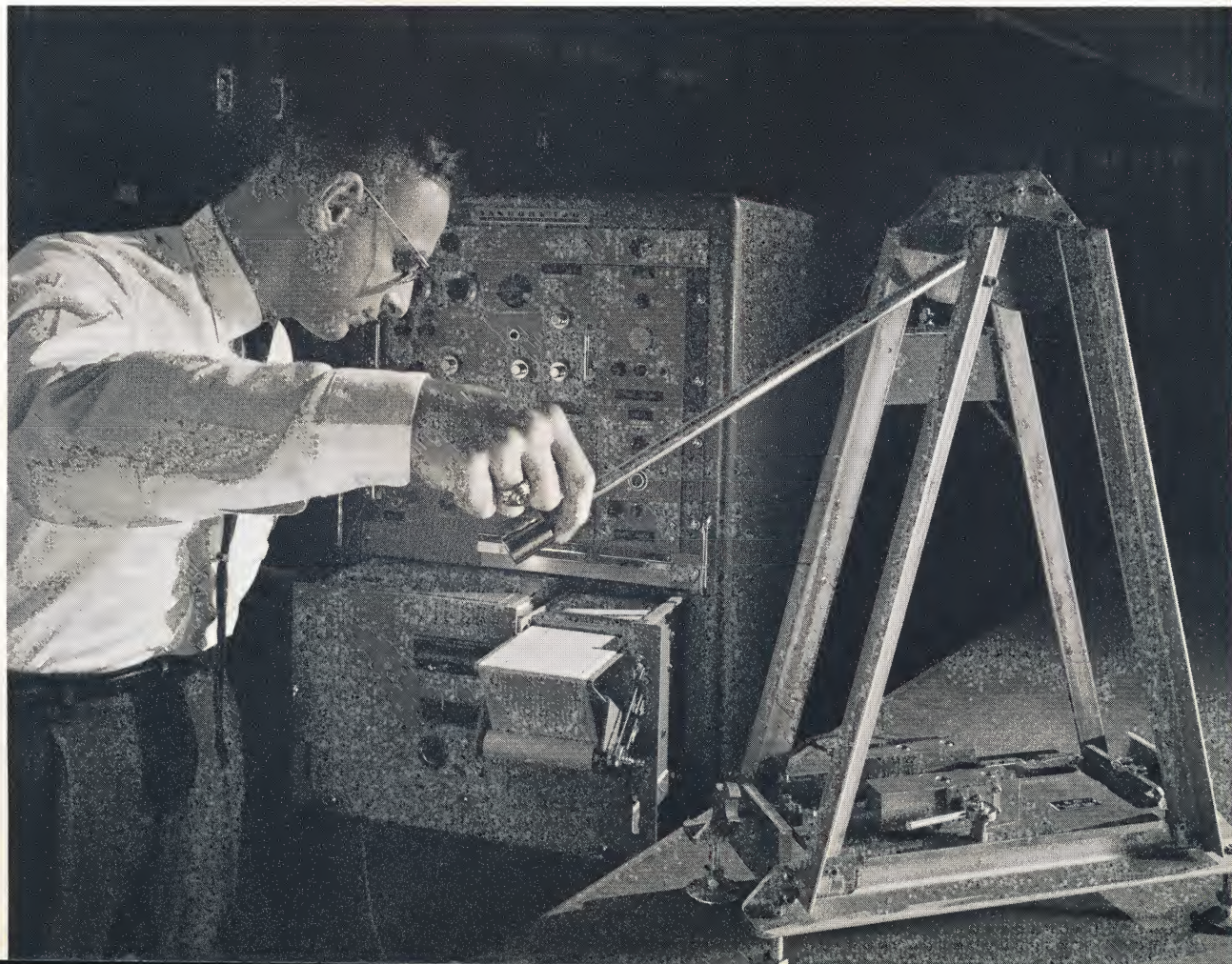
From the graph, you can readily see that Durol base proves to be over 40% stronger (the



end of each curve indicates the breaking point).

But any torture test one engineer can devise, another engineer can improve upon. Take a look at the Mil Shock Tensile Testor (below). This instrument is designed to determine a tape's over-all strength (toughness) by measuring the force required to break a sample. A measured length of tape is held securely between two clamps. Then it is struck and broken by a falling pendulum. Because it has been

raised to a fixed height, the pendulum always delivers a precise and repeatable amount of impact. The energy absorbed by the tape at impact controls the height of the pendulum's backswing. Thus, a measurement of backswing height is a direct measurement of toughness. The strain rate that this device imposes is on the order of magnitude of 200,000% per minute—with enough energy to break any acetate-based tape. How does Durol base compare to conventional acetates? Well, it comes through this test, too, just like an Olympic star. This toughness test also provides a valuable measure of permanent elongation. Durol base's unique "shear-pin" action lets it break clean with minimum elongation (less than 1% compared to 10% for other acetates). Now let's take a look at the effects of surface smoothness on high-frequency response.



all about surface characteristics and frequency response

Visualize a roll of sandpaper $\frac{1}{4}$ -inch wide. Now thread it into your tape recorder and run it awhile. Devastating thought? Sure is. Some poorly made tapes seem just about like that. Here's the story: Iron oxide is actually harder than many types of sand. And each particle of this destructively hard material can exert thousands of pounds of pressure per square inch, cutting a recorder head brutally.

But aside from the abrasiveness of a rough tape, remember the effect that surface irregularities have on high-frequency response. Anything — no matter how small — that prevents the

head from making contact with the entire width of the oxide, results in spacing losses. It doesn't matter how much . . . variations in the surface of a few ten thousandths of an inch are enough to drop a H.F. note by many dbs. More specifically, a space just $\frac{1}{10}$ the wavelength will result in a loss of about 5.5 db!

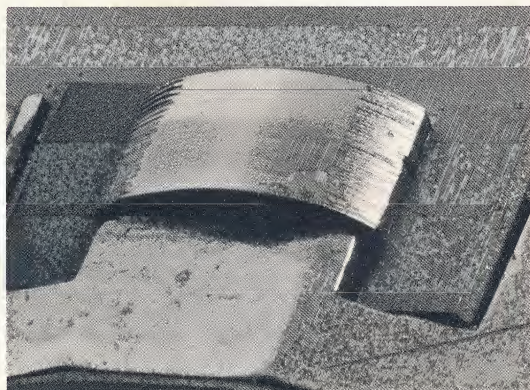
Luckily these two things don't happen around here. And for two good reasons. The first is our "R-type" binder. This resinous material has a number of unique advantages. For example, it covers each particle of iron oxide thoroughly, and be-

cause it can be critically controlled, the iron oxide can be coated to a glasslike smoothness. No other binder, in fact, can be handled like our "R-type" binder. This means that Kodak tape gives you a smoother, more friction-free surface to begin with. Look at the two photomicrographs of tape surfaces at the right. Can you imagine what the tape at the top would do to your recorder heads? To high-frequency response? We'd rather not. That's why we take the trouble to make our tapes with smooth, smooth surfaces, just like the lower picture.

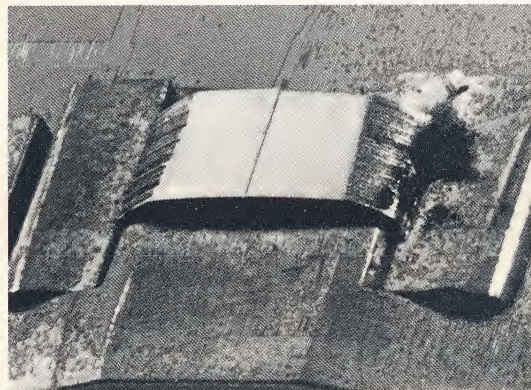
But because we are the pesky, finicky bunch that we are, we go even further. We take our super-smooth surface and just to make certain that your recorder heads will get tender, kindly treatment, we have taken the extra precaution of lubricating the entire thickness of the coating. Not just any lubricant, but a very special one. One that is exclusively ours. Why a special one? Well, here's the story. Out of the thousands of materials available as lubricants, only a few are suitable for use with tape surfaces. The rest aren't good for lubricating anything other than lawn mowers.

A lubricant must lubricate, but not too well

Here are the requirements. Tape must slip over heads (and



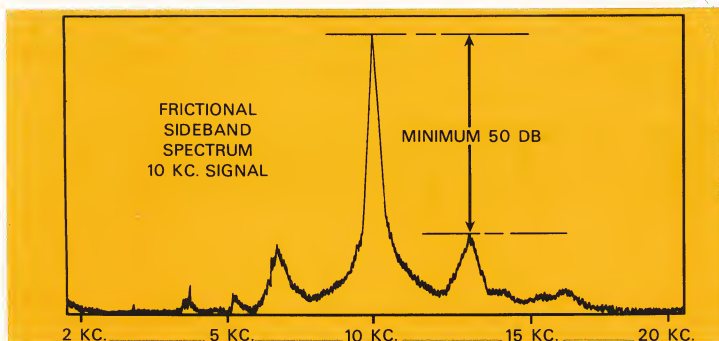
These comparison photographs between new and worn recorder heads illustrate what can happen when a tape surface is rough and dirty. Note in the picture at the right



the head has been flattened and the gap widened. Note, too, the oxide dust that can clog the gap and abrade both tape and head. This head is useless!

pressure pads, too, if your recorder has them), but there must be no slippage at all over the capstan; otherwise, constant speed will suffer. In other words, the ideal lubricant has a combination of characteristics that allows it to glide friction-free (relatively, of course) in certain places and hold fast and not slip at all in others. Designing lubricants that give this sort of performance is something akin to trying to eat your cake and keep it too. Pretty tough to hit on the first try. After a few thousand tries, however, we did hit it, and got some pretty big rewards in terms of recording performance.

Visualize the length of tape from idler to capstan. As it runs it is not just in forward motion, it is in longitudinal vibration as well. About 3000 cps in some recorders, maybe 5000 or 6000 cps in others. This acts as a sort of mechanical a-c ripple superimposed on the d-c motion of the tape, if we may be allowed an electronic metaphor. The result of this is the generation of sidebands that destroy the timbre of the music. Lubrication — although not a snake oil that performs an instant cure—does effectively control the generation of these sidebands. Trouble with sidebands is that they peak way up. Better lubrication suppresses the peaks while reducing friction. It's the sort of action you might get on your nerve ends as a result of running your finger along a blackboard and then stopping. To our way of thinking, sidebands are not effectively squelched unless they are at least 50 db down. And that figure almost becomes one of the many figures of merit that we use when choosing lubricants... the 50 db figure. If a lubricant can't give us that degree of sideband suppression, then out to the lawn mower shed it goes.



Just to make certain that everything that can be going for us, is... we make use of our lubricants in every way possible so that we never miss a bet in terms of quality and/or performance. For example: We incorporate our lubricants into the magnetic coating. And we lubricate the base as well. In that way, all bets are covered. You might have noticed from time to time how some tapes smear their lubricants all over your equipment. You'll never get that sort of "gunking" from a Kodak tape, because our lubricants have an exceptionally high degree of chemical stability. The kind of stability that every record and playback head will appreciate.

With all of the electrical and physical characteristics we've outlined, and their interrelationships, the number of individual things that need controlling runs into the thousands. We have lots of individual controls, but we also have a master control system. It tells us when, where and, to a great extent, just how a roll of tape was made. And we do it by a system of sequential numbering on the back of the tape. Each oxide batch gets an "emulsion number." It is through this number that we can trace a tape back to its earliest origins and compare manufacturing and design procedures to actual field performance. We can tell when that tape was made, what coating machine it was made on, which master roll it came from, and even from which section of that roll it was cut. With this infor-

mation it's an easy matter to run down the complete quality-control test results. Should a user have specific questions about the characteristics of any given roll of tape, we can supply answers. We think it makes a lot of sense to go to all this trouble for quality control.

Backprinting costs us money. We think it's worth it.



all about tape conveniences

It's amazing what good things can happen when you've got a hobby. A lot of our scientists working on KODAK Sound Recording Tape have hobbies. And in almost every case, coincidentally, the hobby is tape recording. And engineers being the sort of restless, dissatisfied people they are, all kinds of off-hours research projects are in progress to give Kodak tape a few extra features in terms of handling ease. One of our boys, for example, decided that he wanted to know just what kind of tape he was using in terms of thickness and base type, even when it was separated from its box. And he wanted to know it at a glance. Another engineer decided that nothing would be more valuable from a quality-control standpoint than a method of knowing just when a given roll of tape was made—even what part of the master web it came from. So we took their suggestions and printed a whole raft of useful information on the base side of the tape. Just to reassure you that you were getting Kodak quality, we even identified ourselves as the manufacturer. This led to quite a stir in the tape business. In an age when more and more companies are taking their names off their products and furtively selling them in unmarked white boxes, we are so proud of the quality

and uniformity of our product that we are putting our name right on the back of the tape itself.

And not just our name. The kind of tape, too. Won't it be nice to know that you are using half-mil-polyester-triple-play every time you are using half-mil-polyester-triple-play? This means that even after Kodak tape has been separated from its original box or reel, you can still identify it. And you'll also know whether or not the reel has been rewound simply by looking at the "Eastman Kodak Co." imprint and noting the direction it reads as the tape comes off the reel. How's that for a time saver?

Those "emulsion numbers" we print on the back for quality-control purposes can be useful to you, too. They're regularly spaced, you know. Every 30 inches. Used in conjunction with the Kodak imprint and the product description, timing and editing will be a breeze!

Familiar with our Thread-Easy Reel? It's really worth knowing about because it cuts fumbling time down to zero. It's so easy to use, it practically threads itself. Here's how... slip the tape through the slot... hit the record button, and you're in business. That's all there is to it. Like greased lightning! There's no need to worry about manhandling your tape either. This reel's a real gentleman!

Smooth surfaces. Bevelled edges. Dynamic balance. All add up to top performance. That, plus the fact that it has a built-in splicing jig, indexing scale and writing surface on *both* sides of the reel, adds a few extra fillips well worth having.

Everything about Kodak tape contributes to its handling ease... even the box it comes in. If you've done any tape recording at all, you've undoubtedly experienced the phenomenon of the two-piece box. It starts off as sort of one-piece (two halves stuck together with a paper hinge), but after a few openings and closings it's literally two pieces. Then comes the dilemma—which top goes with which bottom? That sort of nonsense doesn't happen with a Kodak tape box because it's all one piece to begin with. What's more, there's plenty of room to index your recorded selections. Small things? Sure. But they'll make your recording days a whole lot more enjoyable.

Perhaps the greatest convenience of all is the fact that Kodak tape is available in such a wide variety of types. There's one for every recording purpose. From standard play to triple play. On Durol base or polyester. We also offer the only "2-in-1" tapes available. They combine in a single tape the most desirable properties of what is normally two different tapes. Type 31A... Low-Print/General-Purpose. Type 34A... High-Output/Low-Noise. Premium features at no extra cost. How's that for a bargain! The table at the right outlines the complete Kodak line. Why not try a roll soon; then you can put it through its paces. You'll find there's no tape finer. It's available at electronic supply stores, camera shops, audio departments, specialty shops... everywhere.

TYPE 31A

Durol Base 1½ Mil Std. Play

Type 31A actually combines two tapes in one. First, it is a fine general-purpose tape. Second, it is a low-print tape, having a superb print-through ratio of 53 db. However, output does not suffer as with other low-print tapes. In fact, the output is about 33% greater than conventional general-purpose tapes. Coated on 1½-mil Durol Base, Type 31A is superbly well suited for all standard-play applications.

TYPE 34A

Durol Base 1½ Mil Hi Output

This professional tape has 125% more undistorted output than conventional general-purpose tapes. Yet this increase in output has been at-

tained without the usual increase in print-through. The print-through ratio is equal to that of most other general-purpose tapes. Type 34A also has a second use—low-noise applications. Because of its great dynamic range, tape noise can be greatly reduced simply by lowering the record level. This feature, of course, at no extra cost.

TYPE 21A

Durol Base 1 Mil Extra Play

Low-print oxide layer (same as with Type 31A) coated on 1-mil Durol Base, giving 50% additional playing time.

TYPE 21P

Polyester Base 1 Mil Extra Play

A companion tape to Type 21A, hav-

ing the same low-print oxide layer, only coated on stronger polyester base. Polyester is tempered to reduce stretching.

TYPE 11P

Polyester Base ½ Mil Double Play

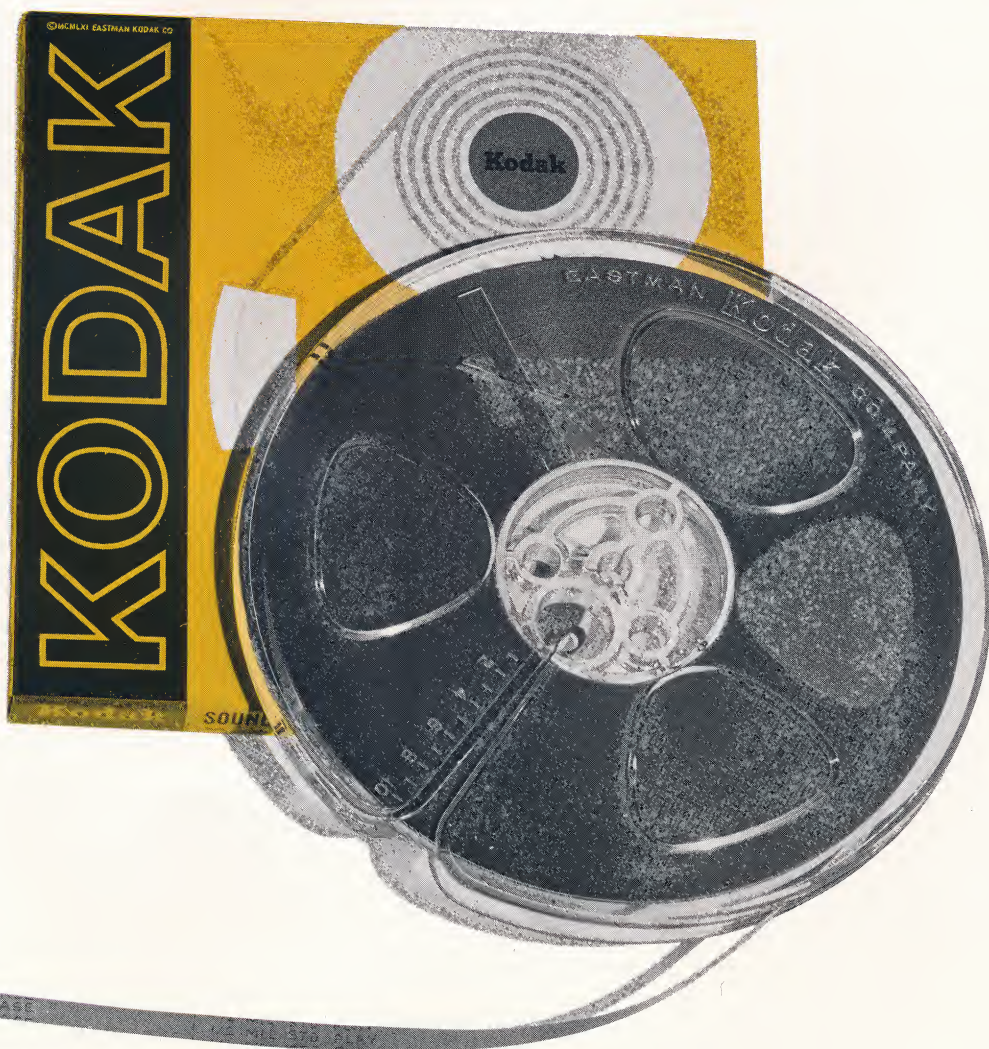
Low-print oxide layer coated on tempered ½-mil polyester base for twice standard playing time.

TYPE 12P

Polyester Base ½ Mil Triple Play

Special high-potency oxide is coated in compact layer on tempered ½-mil polyester base, increasing playing time threefold. Type 12P exhibits superior print-through characteristics, less noise, and higher output than any other triple-play tape.

"KODAK" and "Durol" are trademarks.





EASTMAN KODAK COMPANY, Rochester, New York